performed to detect limb by group differences. Significance level was set at $p \leq 0.05$. Descriptive comparisons were made to historic pre-operative and healthy controls.

Results: Ninety-three subjects were included in this study. Sixteen subjects were lost to follow-up, resulting in 77 subjects included in the final analysis (YES: $N = 18$, 6M/12F, age = 67.11; NO: $N = 59$, 31M/28F, age = 66.80). There were significant main effects of group and limb (Table 1), with the YES group having substantially weaker knee extensors on both limbs (Fig 1). There were no significant predictors of contralateral TKA for either limb. However, the addition of operated limb quadriceps strength to the model improved the significance of the model and was nearly a significant addition to the model ($p = 0.077$).

Conclusions: Given that the subjects who had contralateral TKA were substantially weaker than those who did not, and were weaker than historical group undergoing TKA, these results suggests that quadriceps weakness may play a role in discriminating those who do and do not demonstrate symptomatic progression on the contralateral limb. Future work should evaluate rehabilitation protocols that not only restore operated limb quadriceps strength to at least pre-operative levels. Although knee adduction moment is predictive of OA progression, we did not find that in this analysis. However, previous literature suggests that non-normalized PKAM may be a more clinically relevant measure when analyzing knee OA progression. Therefore, future analyses of incidence of contralateral TKA may include non-normalized PKAM.

Table 1
Clinical & biomechanical outcomes.

Variable	YES		NO		Main Effect of Limb	Main Effect of Group	Interaction Effect
	Operated	Non- operated	Operated	Non- operated			
KOS	0.82 ± 0.13	0.89 ± 0.10	0.86 ± 0.12	0.92 ± 0.10	0.005*	0.068	0.775
Knee pain	0.83 ± 0.86	0.66 ± 0.74	0.59 ± 0.87	0.52 ± 0.73	0.439	0.216	0.745
Quad strength (N/BMI)	15.61 ± 5.97	18.87 ± 8.30	19.01 ± 7.62	21.68 ± 8.51	0.050*	0.041*	0.845
Extension ROM (°)	0.17 ± 3.88	-0.77 ± 3.22	0.44 ± 4.41	-1.91 ± 3.27	0.025*	0.553	0.332
KFM at PKF (N·m/kg·m)	0.27 ± 0.16	0.26 ± 0.21	0.34 ± 0.15	0.34 ± 0.18	0.776	0.017*	0.770
PKAM (N·m/kg·m)	-0.30 ± 0.08	-0.38 ± 0.12	-0.29 ± 0.12	-0.38 ± 0.14	0.000*	0.865	0.949

*$p \leq 0.05$ (¶ (-) = hvperextension. (+) = extension loss).

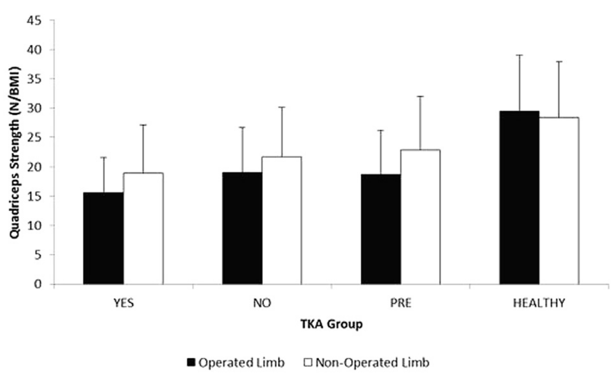

Figure 1. – Operated and Non-operated limb quadriceps strength in those that received contralateral TKA (YES), did not receive contralateral TKA (NO), at end-stage unilateral knee OA (PRE), and healthy controls (HEALTHY).

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COMPOSITION OF THE KNEE INDEX, A THREE-DIMENSIONAL BIOMECHANICAL INDEX FOR KNEE JOINT LOAD, IN SUBJECTS WITH MILD TO MODERATE KNEE OSTEOARTHRITIS

B. Clausen [†,‡], T.P. Andriacchi [§,||], D.B. Nielsen [¶,#], E.M. Roos [†,‡], A. Holsgaard-Larsen [¶,#]. [†] *Univ. of Southern Denmark, Odense M, Denmark;* [‡] *Dept. of Sports Sci. and Clinical Biomachanics, Odense M, Denmark;* [§] *Stanford Univ., Standford; Veterans Administration, Palo Alto, CA, USA;* [||] *Dept. of Mechanical Engineering, Dept. of Orthopedic Surgery, Stanford, CA, USA;* [¶] *Univ. of Southern Denmark, Odense C, Denmark;* [#] *Dept. of Orthopaedics and Traumatology, Odense Univ. Hosp., Odense C, Denmark*

Purpose: Knee joint load is an important factor associated with progression of knee osteoarthritis. The knee adduction moment (KAM) is an indicator of medio-lateral knee load distribution. However, KAM only includes frontal plane moment and has recently been found insensitive in subjects with mild to moderate osteoarthritis. The Knee Index has been developed to include moments from all three planes (frontal, sagittal and transversal) and was able to distinguish between pain relief induced by placebo, NSAID or opioids. However, to help interpret the underlying biomechanical characteristics of the Knee Index, the respective contributions of the knee moments derived from the three planes are important to determine.

The purpose of this study was therefor to investigate how the frontal, sagittal and transversal moments contribute to the Knee Index, a novel biomechanical index of joint load for the knee, in patients with mild to moderate knee osteoarthritis.

Methods: The contribution of frontal, sagittal and transversal plane knee moments to the Knee Index was investigated in 24 subjects (13 women, age: 58 ± 7.6 years, BMI: 27.1 ± 3.0) with clinically diagnosed mild to moderate knee osteoarthritis according to the ACR criteria. Three dimensional gait analysis was performed using a 6-camera Vicon MX (Vicon, Oxford, UK) movement analysis system (100 Hz) with the Plug-in-Gait marker set. Ground reaction forces were recorded (1000 Hz) by two AMTI force-plates (AMTI, OR6-7, Watertown, MA, USA) embedded at floor level. Subjects walked barefoot at self-selected walking speed. The trial (out of 5 trials) representing the median velocity was selected for further analysis. The first peak (approximately 50 % of stance phase) magnitude Knee Index (calculated by the root mean square of frontal, sagittal and transversal knee moments (for equation, see figure 1A) and the corresponding knee moments (at the same time points) from all three planes were calculated for the knee diagnosed with OA using inverse dynamics. Percentage distribution of the contributors of the Knee Index (for equation, see figure 1B).

Results: Frontal plane kinematics contributed with 60.0% (SD 25.6) of the Knee Index while sagittal plane kinematics contributed with 40.5% (SD 26.1) and transversal plane kinematics contributed with 0.2% (SD 0.3). A substantial inter-subject variation in the relative contribution of the flexion and extension moment components to the Knee Index was observed (see figure 2).

Conclusions: Our findings in these subjects with mild to moderate knee OA support the notion that the primary contributor to the Knee Index is the frontal plane kinematics (i.e. the knee adduction moment), and secondarily the sagittal plane kinematics (i.e. the knee flexion moment). The transversal plane moment did not contribute to the Knee Index. It is hypothesized that the Knee Index's sensitivity to pain comes from the inclusion of the sagittal plane.

The present substantial inter-subject variation gives interest to investigate the relative contributions as predictive of future clinical changes. The present findings add to the knowledge of knee joint load distribution and OA.

A. $$Knee\ Index = \sqrt{\left(\frac{(Frontal\,plane\,moment^2 + Sagittal\,plane\,moment^2 + Transversal\,plane\,moment^2)}{3}\right)}$$

B. $$\%Frontal = \left(\frac{\left(\frac{Frontal\,plane\,moment^2}{Knee\,Index^2}\right)}{3}\right) * 100\% \qquad \%Sagittal = \left(\frac{\left(\frac{Sagittal\,plane\,moment^2}{Knee\,Index^2}\right)}{3}\right) * 100\%$$

$$\%Transversal = \left(\frac{\left(\frac{Transversal\,plane\,moment^2}{Knee\,Index^2}\right)}{3}\right) * 100\%$$

Figure 1. Equation of the Knee Index and percentage distribution.

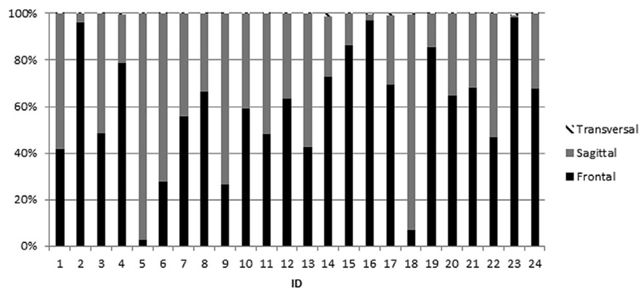

Figure 2. Bar chart of percentage distribution of the contributors to the Knee Index.

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ASYMPTOMATIC OBESE SUBJECTS WITH MR-BASED INDICATIONS OF KNEE OA HAVE ALTERED GAIT KINETICS

S. Edd [†,‡], K. Blazek [†,‡], J. Asay [†,‡], T. Andriacchi [†,‡], J. Favre [†]. [†] *Stanford Univ., Stanford, CA, USA;* [‡] *VA Palo Alto RR&D Ctr., Palo alto, CA, USA*

Purpose: Obesity is an established risk for knee osteoarthritis (OA), yet the association between obesity and OA remains unclear. Previous studies that compared gait mechanics of young asymptomatic, older asymptomatic, moderate OA, and severe OA subjects established that specific features of gait mechanics (reduced first peak extension moment) were present in older healthy individuals and was more reduced with increased OA severity, suggesting that a reduced extension moment preceded clinical symptoms of OA in an aging population. Similarly it is known that the peak knee flexion moment is decreased in the presence of OA-related knee pain. Given the risk for developing obesity-associated OA it would be important to test if similar gait related changes in the flexion/extension moments precede clinical OA symptoms. A population of asymptomatic obese subjects with magnetic resonance imaging (MRI) signs of OA (Asymp-OA) were available for testing the following hypotheses: H1) a peak flexion moment no different than that of a matched (age, height weight, gender) healthy Control group and H2) a smaller first peak knee extension moment as compared with the Control group.

Methods: As part of a larger IRB-approved study on gait in obese individuals, bilateral knee MRI scans (3D SPGR) were taken of subjects who self-reported no chronic pain or injury to the lower extremities or back. These scans revealed that a subgroup ($n = 12$, 3 M) had early signs of osteoarthritis, specifically cartilage defects in either the patellofemoral or tibiofemoral joint, with or without meniscal degeneration. The demographics of this subgroup were: 1.7 $\pm$ 0.1 m (mean $\pm$ SD), 93.2 $\pm$ 11.2 kg, BMI 34 $\pm$ 4, and 51 $\pm$ 7 years old. From the same larger study population, age-, gender-, height-, and weight-matched individuals were used as a control group for comparison ($n = 20$, 8 M). An opto-electronic motion capture system and embedded forceplate were used to analyze knee mechanics while subjects performed walking trials at a self-selected normal walking speed. The study limb was selected randomly for the Control subjects and the more affected limb, based on MRI, was analyzed for the Asymp-OA subjects. Knee kinetics were calculated using a standard method (BioMove, Stanford). First peak extension moment and peak flexion moment (positive %BW*Ht) were compared between the Asymp-OA and Control groups using one- and two-tailed unpaired Student's t-tests, respectively (Fig 1). A Bonferroni adjusted (2 tests) p-value threshold of $p = 0.03$ was used.

Results: The first peak extension moment was significantly less in the Asymp-OA versus the Control group (2.2 $\pm$ 0.8 vs 2.8 $\pm$ 0.8 %BWxHt, $p = 0.02$, Fig 2). There were no group differences in peak flexion moment (2.2 $\pm$ 1.1 vs 2.4 $\pm$ 0.9 %BWxHt, $p = 0.6$), walking speed, stance duration, or ground reaction forces.

Conclusions: The results indicate that there are specific gait characteristic that appear in obese subjects with structural cartilage degeneration that are not present in obese subjects with healthy cartilage. Specifically these results suggest a reduced first peak extension moment as a potential gait marker for the very early stages of OA in the obese, which occurs before the onset of symptoms. The finding that there was no group difference in the peak flexion moment was consistent with the patients reporting no pain, as this flexion moment has been reported as one of the most sensitive gait metrics for pain. This finding suggests that the gait feature (reduced extension moment) of the Asymp-OA group was not an adaptation to pain but may be attributable to muscular, neuromuscular, or soft tissue alterations. The characteristic of the extension moment near heel strike could have implications for interventions if these gait changes are found to provoke the onset of disease.

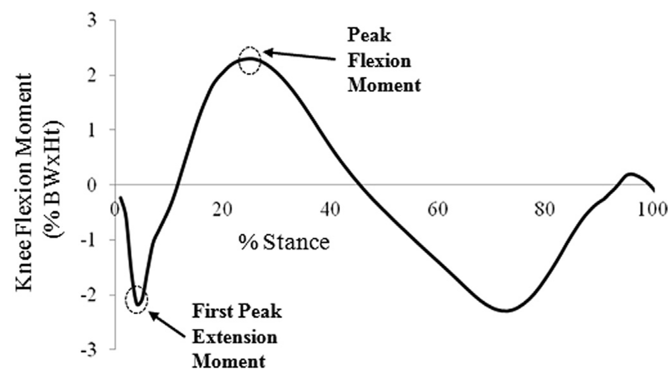

Figure 1. First peak extension and peak flexion moment definitions.

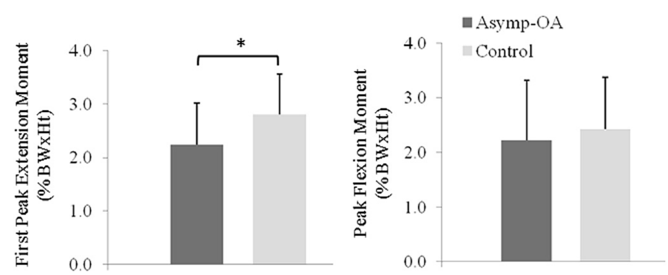

Figure 2. Mean first peak extension moment and peak flexion moment comparison. Errors bars depict standard deviations. $^{*}p = 0.02$.

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CORRELATION BETWEEN 3D KNEE KINEMATICS AND TIBIO FEMORAL RADIOGRAPHIC OSTEOARTHRITIS GRADING SYSTEM

J. Blouin [†], N. Mezghani [‡], T.D. Cooke [§,‖], M. Brean [‖], A. Fuentes [¶]. [†] *École de technologie supérieure, Montreal, QC, Canada;* [‡] *TELUQ, Montreal, QC, Canada;* [§] *Queen's Univ, Sch. of Rehabilitation Therapy, Perth, ON, Canada;* [‖] *OAISYS, Perth, ON, Canada;* [¶] *Emovi, Montreal, QC, Canada*

Purpose: Radiographic grading scheme have shown to be sensitive to the deterioration of osteoarthritic knees. However, previous studies have suggested that radiological assessment does not correlate well with clinical symptoms. Few analyses were done in order to link the radiographic scores to joint function (3D kinematics). The objective of this study is to assess if tibio femoral (TF) knee osteoarthritis (OA) grading scores are correlated with functional knee kinematics.

Methods: Forty-seven knees from 35 patients with a confirmed diagnosis of tibio femoral OA underwent a knee functional assessment (KneeKGTM, Laval, Canada) measuring, in clinic, 3D knee kinematic during treadmill gait. All patients also had a weight bearing x-ray of their knees that were graded using OAISYS radiographic scheme. This x-ray score is composed of 5 sub scores (FA_TA (femoral and tibial anatomical axis), JS (joint space), FO (femoral osteophytes), TE (tibial erosion) and SU (subluxation)) and one total score (TS). Those scores are applied on the most damaged knee compartment: medial or lateral. All the patients in this study had predominantly the medial compartment affected. Knee kinematic parameters were evaluated in all three planes of movement (sagittal, frontal and transverse) going from punctual knee angle value at specific times of the gait cycle (GC), to ranges of motion (ROM) and mean values for specific phases of the GC.
Using SPSS Statistics software, Pearson's Correlation Coefficient was first evaluated between TS and each kinematic parameter to find a preliminary result of the correlations. Kinematic parameters that showed significant correlation (p <0.05) were further investigated. A multiple linear regression (MLR) was done for each of these parameters as dependent variable with the sub scores (FA_TA, JS, FO, TE, and SU) as independent variables.